DOCUMENT RESUME

ED 183 495 SP 013 856

AUTHOR Stelmach, George E.
TITLE Toward an Information Processing Approach in Motor Behavior Research.
SPONS AGENCY National Inst. of Education (DHEW), Washington, D.C.
PUB DATE Jan 77
GRANT NE-G-00-3-0099
NOTE 21p.; Paper presented at the Joint Meeting of National College of Physical Education Association for Men and National Association of Physical Education for College Women (Orlando, FL, January 7, 1977).

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS Behavioral Science Research; Behavior Patterns; *Cognitive Processes; *Motor Reactions; Pattern Recognition; Perceptual Motor Coordination; Perceptual Motor Learning; *Research Criteria; *Research Methodology

ABSTRACT

It is argued that the current theoretical orientation of motor behavior research toward information processing is only at the descriptive level. An outline of requirements for motor behaviorists to discover the mental operations that precede motor performance is presented. It is suggested that unless basic knowledge is obtained on how movement information is perceived, coded, and retrieved, practical applications to obtain optimal learning and retention will be ill-founded. (JD)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED183495

TOWARD AN INFORMATION PROCESSING APPROACH IN MOTOR BEHAVIOR RESEARCH[1]

George E. Stelmach
Motor Behavior Laboratory
University of Wisconsin
Madison, Wisconsin 53706

MAR 5 10 44 AM '79

Paper Presented at the Joint Meeting of
National College of Physical Education Association for Men
and
National Association of Physical Education for College Women
Orlando, Florida
January 7, 1977

U S DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL NATIONAL INSTITUTE OF EDUCATION POSITION OR POLICY

"PERMISSION TO REPRODUCE THIS MATERIAL IN MICROFICHE ONLY HAS BEEN GRANTED BY

George E. Stelmach

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

[1] Preparation of this paper was supported by a Grant from the National Institute of Education NE-G-00-3-0099

SP 013 856

The ultimate goal of motor behavior research is to understand, explain, and predict how the human organism performs and learns a variety of motor skills so that educators can create and manipulate an advantageous environment which ensures optimal development in every individual. While this goal is quite appealing, I think we would all agree that we are a long way from achieving it. During the past ten years, the motor learning and control area has captured an inordinate amount of experimental and theoretical attention in physical education and psychology (17). It has been a period of excitement, dither and controversy. For the most part, during this period there has been a lot of discussion about how motor behavior has shifted from a product-oriented approach to one which stresses the mechanisms that underlie learning and control

Initially, much of motor behavior research was ~~shaped~~ dominated by the attitude that learning is the ~~primary~~ only aspect of the skill ~~situation~~ acquisition we should ~~be concerned with~~. Consequently, the motor behaviorist searched for the empirical relations governing acquisition, transfer and retention (17). However, this product oriented approach has produced voluminous amounts of empirical research which conveys little knowledge regarding the acquisition and retention of motor skills, lacks a common organizational structure, and provides little insight into the cognitive operations subserving performance. One only needs to look at motor behavior research to find it quite disjointed despite overtures toward a processing approach (16). Adams attributes the lack of a theoretical orientation to the motor behaviorist's continual interest in applied research problems. I think the problem is more basic than that; it reflects the lack of a conceptual framework on the part of the scientists.

In contrast, contemporary students of motor behavior are beginning to discuss the cognitive elements associated with motor behavior (13, 18). Types of questions

being asked are: What are the mechanisms or processes responsible for registering, storing and retrieving movement information? What are the characteristics of these processes and how do the operate? Finally, how is this information integrated with the effector system to produce an observable skilled action?

The main reason for the paradigm shift has been the general understanding that when differences are observed in behavior with product-oriented research, it is not known what the differences are attributed to concerning the processes subserving performance. A second major reason for the rapid ascent of information processing theory was the advent of the computer. This was not because the computer could analyze data more thoroughly, rather it was because the activities of a computer itself were similar to cognitive processes. Computers accept information, manipulate symbols, store items, retrieve them, classify inputs and recognize patterns. The coming of the computer provided the psychologist for the first time with support that cognitive functions were real and could be examined (11).

Insert figure 1 about here

Current behavioral research, which defines the field of learning and cognitive psychology, can be characterized in terms of its concern with the processing and transformation of information (5). The central assumption of this information processing approach is that a number of independent mental operations or processing stages occur between stimulus and response (21). In addition these processing stages are sequential, they take time, they only transform or process available information, and they make the transformed information available to the ensuing stage of processing (10). Information processing methodology has its origins in Donders' method (4) which is based on the idea that the time between stimulus and response is occupied by a train of successive processes or stages (see Figure 1). Basically, this method sought to study hypothesized mental

processes by including or excluding their use in the experimental task. However, it is unlikely that one can insert or delete processing stages without altering the nature of identical stages between tasks (10). Subsequent models began to compartmentalize the sequence of processes into sensory registration, perception, decision, and effector mechanisms (3). With increasing sophistication, introspective logic and measurement concepts, theories began incorporating encoding, storage and retrieval concepts (see Figure 2).

Insert Figure 2 here about

Sternberg's Additive Factor Method is the primary reason why the information processing approach has attained such prominence in experimental psychology. In this paradigm the experimenter does not attempt to insert or delete a processing stage, but simply attempts to influence the amount of processing at a given stage. First, the experimental task must be analyzed to determine the type and number of stages involved in the task. Next, at least two independent variables which are expected to affect the processing of two different stages must be chosen. Using a factorial design, each level of one independent variable is crossed with e every level of the other independent variable(s). The investigator then tests the experimental hypothesis; that each independent variable affects separate stages of processing.

Using variations in the foregoing procedures the processes that underlie behavior have been studied in the areas of stimulus detection, selective attention, iconic memory, pattern identification, short-term scanning, retrieval, and forgetting. Furthermore, the techniques used to study these processes have been diverse, including reaction time measurements, accuracy of threshold stimuli and the retention of clearly perceived stimuli (15).

In contrast to the early product-oriented research, most contemporary motor

behaviorist are using jargon which falls under the general rubric of information processing (12). Correspondingly, there has been alot said about how the area has changed. I think if you examine motor behavior research carefully you will find that it has not changed very much. The jargon has changed but the experiments have not. While it is true motor behaviorists have begun to ask questions about the knids of processes occurring as the individual performs and learns a response, there has been no great change in methodology associated with the orientation toward processes. Looking through recent published articles, the vast majority of studies are still examining recall, fatigue, variability, social interactions, transfer and timing in a product-oriented manner. With further inspection, it becomes evident that a systematic attempt to precisely differentiate the stages of processing with the exactness witnessed in the visual and auditory modalities is non-existent. Consequently, it is virtually impossible to organize the existing research in a manner which allows one to intelligently evaluate our current understanding of the processes that underlie movement behavior.

A motor behavior theory that has received an extreme amount of theoretical and experimental attention is Adams' Closed Loop Theory (2). I t has been described as a process oriented closed-loop theory because it focuses on error detection and correction mechanisms and discusses the development of memory traces. While the theory is based on empirical evidence, has testable predictions, has received some experimental support, and is perhaps the best motor learning theory available, it is not very process oriented and verges on being very associationistic. Its major postulate is that the residue of a sensory experience lays down a trace of the movement experience in memory which provides the basis for later recognition or recall. In addition, the strength of the trace increases with repetition and decays with time or new learning. As such, Adams' Closed Loop Theory does not delineate how movement information is perceived, stored and retrieved with any degree of clarity. Thus it has no existing framework to study

and isolate information processes in a consistent and coherent manner.

This theory was followed by the Schema theory proposed by Schmidt (13) which evolved from an attempt to take the strong parts of previous theories adding modifications and extensions so that the new theory would be able to deal with previous limitations. Schmidt (14) proposes schemata, which are defined as the relationship established from past experience between actual outcomes, response specifications and sensory consequences. An elaborate flow chart describes how the schemata are developed and to describe the mechanisms involved in motor learning. However, the theory and its flow chart do not provide a framework for the systematic investigation of the mental operations that subserve skilled responses. As described, the theory provides no direction for isolating mechanisms or processing stages. In fact the only clear prediction I can find from the theory is that variability of practice should facilitate the development of the schema.

It is not my intention to criticize these theories. I think they make a genuine contribution and are vast improvements over previous ones. My intent is just to show that they are only process-oriented at a descriptive level and do not provide an understanding and explanation of the processing stages between the stimulus and response. Thus both theories tell us little about how information is transformed, coded, and stored.

Surprisingly, there is no systematic motor behavior research that attempts to precisely define and differentiate the stages of processing as in the visual and auditory modalities. This is partially due to the lack of a common theoretical framework and corresponding improvements in experimental methodology. An information processing approach prescribes a particular methodology which has not been adopted for the most part in motor behavior. By mehtodology, I am not referring to expertise in wiring reaction time clocks, or other apparatus, but rather ways of solving the problems of controlling experimental comparisons and interpreting data that are necessary for empirical exploration toward general principles; from

limited fact toward theory. Cognitive psychology as made progress by using methods that have allowed the isolation of the processes underlying behavior. It has been done through improvements in methodology which clearly demonstrates that advances in psychological theory depends upon advances in methods. For to date, there has been little information processing methodology transplanted to motor behavior research, and at present current inferences about processing are strictly at the descriptive level, with little corresponding experimental work.

What must we do in motor behavior research if we are to move toward a processing approach?

1. I think we need to adopt an information processing framework. Adopting this point of view will provide a conceptual framework for attacking behavior and will project an organizing influence on ideas, concepts, and attitudes which make it possible to retrieve, from diverse sources of information, that required to solve some of the mysteries of motor behavior. Furthermore, an information processing framework will enable us to study methodological, logical and theoretical issues in a consistent and coherent manner as well as provide a tool to summarize our findings and predict behavior (9). This means we should not be content with describing how movement information flows through the human organism from perception to response execution; rather efforts must be made to delineate the role of the psychological processes involved.

2. We need to borrow some of the methodology currently being used in cognitive psychology. This will not be an easy task; since one of the difficulties of incorporating information processing methodology in motor behavior is that most of the tasks we are interested in take too long to perform and the amount

of processing is difficult to control. The kinesthetic modality seems to have rather diffuse machinery. The flow of movement information in the nervous system is not funneled through a single structure analogous to the retinal or to the basilar membrane. Nothing in movement correcponds to the momentary retinal image, which serves as the input in most studies of vision or to the spectrum of continuous sound in audition. With movement there are continuous changing stimuli from muscles and skin, positions of the joints, velocities of the moving limbs and other related sources (6). It is apparent that the processes associated with vision and audition are somewhat easier to study than those associated with active movement. However, I think there are several places to begin our processing approach to motor behavior.

We must initially modify our techniques so it is possible to present movement information in an extremely fast yet controlled manner which enables us to examine the perceptual side of a response. One possible place to start would be to present somatosensory information in the form of vibrotactile stimulation. It is possible to present this type of stimuli very quickly and control the amount of processing. Doug Larish, a graduate student in my lab, is attempting to present tactile information in a manner analogous to auditory and visual information which has been so successful in cognitive psychology. It might be argued that this type of information is qualitively different from other sources of movement information (i.e. proprioception), however, it is believed that the tactile sense is a pertinent source of information which can be relayed to the higher centers and used to assist motor learning and control. The state-of-the-art

is so primitive our research must begin with a source of information that is easily controlled, manipulated, and presented for short durations. The initial questions of interest are: Is there a preperceptual store for somatosensory information? What are the properties of the store? Is this information stored peripherally or centrally? What is the temporal course of recognition (encoding)?

Another research avenue which is appealing would be to examine whether movement information can be stored and retrieved with any degree of accuracy when the amount of processing is limited and controlled. For example, imagine an experimental situation where all five fingers are simultaneous moved short distances, in one of four directions. On a given trial, all fingers would be moved in a fixed combination and after a variable delay of 300-1000 msec. A light would cue the subject to repoduce the movement of one or more fingers. Is there a brief storage of this type of movement information and how accurately can it be retrieved? Variations in the foregoing procedures would allow examination of the temporal course of the encoding process which is fundamental to recognition.

The foregoing are only suggested places to begin our research efforts. Perhaps there are several other places to begin which would also produce significant findings such as the interaction of proprioceptive and visual codes or the masking of proprioceptive information during dynamic movement or at specific locations. Despite how we start, it should be clear that if the motor behaviorist is to become process-oriented, the incipient stages of processing must be studied because initial perceptual processes determine subsequent mental operations.

3. It seems that most of our theorists have been primarily interested in explaining the course of learning as a function of practice (Adams (2) Gentile (6), Schmidt (13,14)). That is they focus on the systematic changes in behavior that occur as a consequence of experience. While I think this is a worthwhile enterprise, I don't see how these theories can be expected to be accurate. It is obvious our goal is to develop theories that describe learning, however, we must understand how information is perceived, stored and retained before we can expect much progress. We should be concerned with the question of what is learned rather than describing how performance changes over time. Motor learning is more than a collection of performace changes, and that understanding it requires more than performing descriptive type analyses. We need to know how acquisition and control processes are developed and maintained and how structural constraints impose capacity limitations upon the output of control processes (8). We need theories that precisely document the mental operations that subserve performance. When we have good data and viable theories that do this, the job of accurately describing learning and of developing theories that have generality will be easier.

4. We need to concern ourselves less about whether the tasks used or the experimental situation has direct practical application. I believe the best way to proceed is to use the kind of tasks necessary to study the processes we are interested in. The biggest drawback of this view is that tasks and techniques used often create artificial situations which differ from the real world in a number of ways. While it is sensible to require

experiments that represent everyday life situations and are ecologically valid, criticisms are only germane and worthwhile if they are specific. Tasks should not be evaluated on this basis but on whether they can be used to effectively study the variable(s) of interest. The question is not really whether research should or should not be relevant to real-life problems, no one wants his activities to be basically trivial, but whether relevance must be immediate or remote. Research utilizing visual displays or complex waveforms does not have direct ecological validity but has contributed much to our understanding of how information is processed in these modalities. While some may say this research approach is too basic, just remember that understanding precedes application. Without the understanding of behavior and performance that basic research supplies, practical approaches or programs intended to solve pressing human learning problems will fail.

5. We need to train scientists who understand the nature of scientific inquiry. With the current state of affairs, it would be difficult to get many investigators to agree on where to go from here to unravel the processes that underlie behavior. That is not important though, if investigators understand scientific inquiry and develop strong research programs. I believe these programs should proceed in a systematic manner. First, one gains some support for a theory or model and examines its sensitivity to perturbations as predicted (5). Then one interprets the new experiment within the framework of the model. If the results seem enlightening one then re-evaluates both the model and the state of knowledge concerning the phenomenon at issue with the

new result added and the model adjusted if necessary. A major implication of this aspect of scientific inquiry is that one cannot expect anything theoretically significant to come from the one-shot attempts to test hypotheses. One only needs to look at published articles to realize that one-shot attempts are still very much in vogue in motor behavior. Some of our most well-known scientists publish single isolated findings and journey regularly from topic to topic. It should be obvious from the foregoing that progress comes only from the continuing interplay of theory and experiment.

6. A A multidisciplinary strategy is essential if we are to understand the many-faceted nature of motor behavior. Recently, there has been a surge of interest in motor behavior from various sources other than Physical Education. Besides our quest to answer questions about practical problems in motor learning and sport, there is the experimental psychologist who is interested in generating a complete model of human performance, which has here-to-fore neglected the kinesthetic modality. There is also the increasing concern of engineers for characterizing man's perceptual motor performance as an element in their analyses of control systems. An additional contributing group is the neurophysiologist sho now recognizes the importance of higher-level cortical activity in motor learning and control.

With emerging data bases, it would be naive to assume that any one of them will completely document the mental operations that underlie motor behavior. The evolution of the human organism has developed a fantastically multi-layered system that changes or is mediated in so many ways that it almost defies analysis. The

> emerging picture of what a motor behavior investigator needs to know and needs to do in order to pursue his specialty effectively is a bit staggering. It is hoped that future investigators are part of a genuine multi-disciplinary enterprise in which acquaintance with a wide variety of concepts and methods is essential, if future research is to have impact beyond some very narrow subplot of motor behavior.

In this paper I have shown that the current theoretical orientation of motor behavior research toward information processing is only at the descriptive level. With no existing framework that requires consistent research efforts, little if any experimental work that manipulates information processes is being carried out. Further, I briefly outlined what I think needs to be done if the motor behaviorists are to become dedicated to discovering the mental operations that precede motor performance. While the task will not be easy, significant progress can be made. It is obvious that understanding motor skill goes far beyond perception, decision and effector processes and that studying them will not provide all the answers. However, a processing approach to motor behavior will allow some insight into how and why people perform as they do. The primary implication being that unless basic knowledge is obtained on how movement information is perceived, coded and retrieved practical applications to obtain optimal learning and retention will be ill-founded.

REFERENCES

(1) Jack A. Adams, Human Memory (New York: McGraw-Hill, 1967).

(2) Jack A. Adams, "A Closed Loop Theory for Motor Learning," Journal of Motor Behavior, 1971, 3, 111-150.

(3) Donald E. Broadbent, Perception and Communication (New York: Pergamon Press, 1958).

(4) F.C. Donders, "On the Speed of Mental Processes: 1868-1869," Attention and Performance II (Ed) W.G. Koster, Acta Psychologic 1969, 30, 412-431.

(5) W. K. Estes, "Handbook of Learning and Cognitive Processes," Vol.1, Introduction to Concepts and Issues, (New Jersey: Lawrence Erlbaun Associates, 1975).

(6) H. M. Gentile, "A Working Model of Skill Acquisition with Application to Teaching," Quest 1972, 17, 3-23.

(7) Steven W. Keele and Jeffery Summers, "The Structure of Motor Programs." in Motor Control: Issues and Trends. (Ed) George E. Stelmach, (New York: Academic Press, 1976).

(8) J. A. Scott Kelso and George E. Stelmach, "Central and Peripheral Mechanisms in Motor Control," in Motor Control: Issues and Trends, (Ed) George E. Stelmach, (New York: Academic Press, 1976).

(9) Ronald G. Marteniuk, Information Processing in Motor Skills, (New York: Holt, Rinehart and Winston, 1976).

(10) Dominic W. Massaro, Experimental Psychology and Information Processing, (Chicago: Rand, McNally College Publishing Company, 1975).

(11) Ulric Neisser, Cognition and Reality, (San Francisco: W. H. Freeman, 1976).

(12) Richard W. Pew, "Toward a Process-Oriented Theory of Human Skilled Performance," Journal of Motor Behavior, 1970, 2, 18-24.

(13) Richard A. Schmidt, "A Schema Theory of Discrete Motor Skill Learning," Psychological Review, 1975, 82, 225-260.

(14) Richard A. Schmidt, "The Schema as a Solution to Some Persistent Problems in Motor Learning,Theory," in Motor Control: Issues and Trends, (Ed) George E. Stelmach, (New York: Academic Press, 1976).

(15) Richard M. Shriffin, "Capacity Limitations in Information Processing. Attention and Memory," in Handbook of Learning and Cognitive Processes, (Ed) W. K. Estes, Vol.4 (New Jersey: Lawrence Erlbaun Associates, 1976).

(16) Robert N. Singer, Motor Learning and Human Performance, (New York: MacMillan, 1975).

(17) George E. Stelmach, Motor Control: Issues and Trends, (New York: Academic Press, 1976).

(18) George E. Stelmach and Hugh D. McCracken, "Storage Codes for Movement Information," in Attention and Performance VII, (Ed) Jean Requin, (New York: Lawrence Erlbaun Associates, 1976).

(19) Saul Sternberg, The Discovery of Processing Stages: Extensions of Donders' Method," Acta Psychologica, 1967, 30, 276-315.

(20) W. C. Waugh and D. A. Norman, "Primary Memory," Psychological Review, 1965, 72, 89-104.

(21) Allan T. Welford, Motor Learning, (New York: Scots Foreman, 1976).

Footnote

1. Appreciation is extended to Doug Larish who did much background work and offered constructive comments during the development of this manuscript.

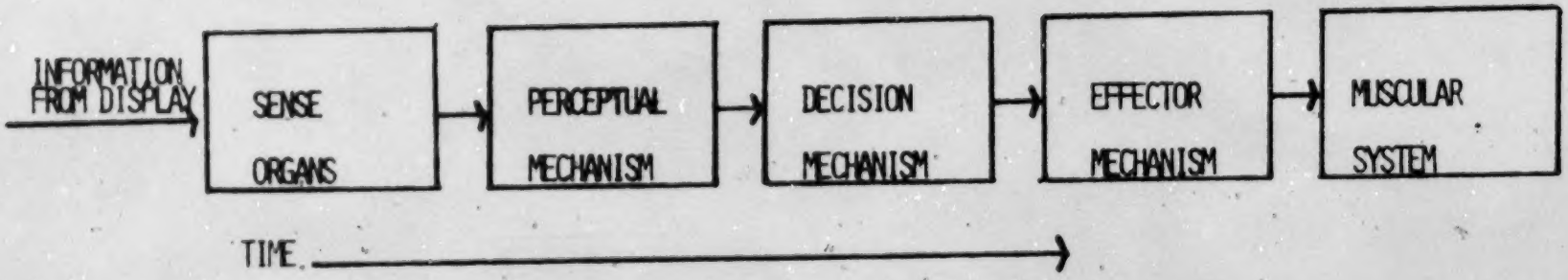

Figure 1. A simple information processing model

From Massaro, 1975

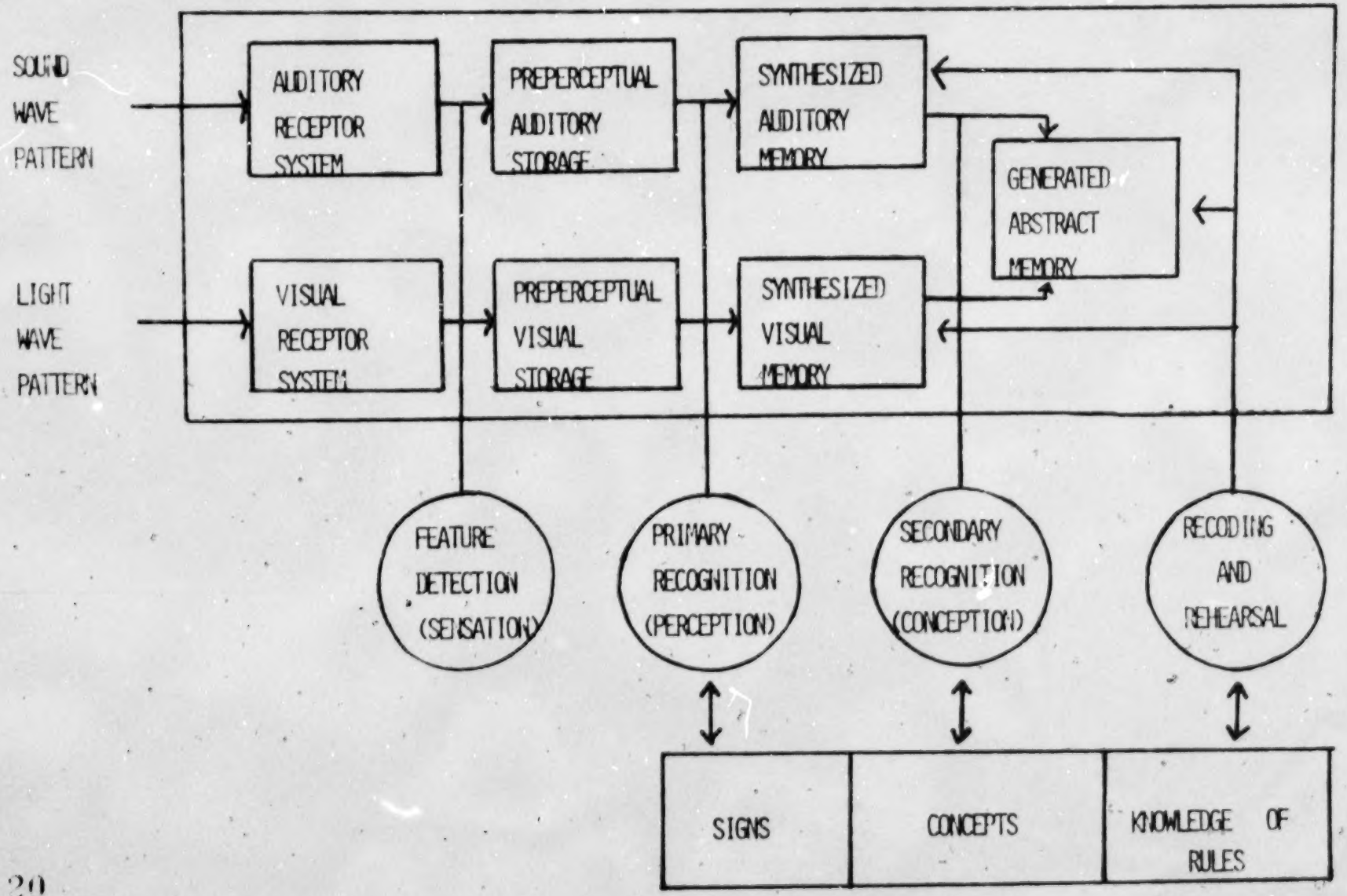

Figure 2. A Complex Information Processing Model from Massaro (10)